Gravitational Lensing Optical Lab

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Purpose
To gain an intuitive understanding of gravitational lensing via an optical lens recreation

Materials
Lab manual, sheet of graph paper, Hubble Deep Field image, and an optical "gravitational" lens

Procedure
In this lab, you will use an optical lens, shaped to simulate a gravitational lens. When observing, close one eye and look directly down the center of the lens. Keep your eye aligned with the center of the lens when you move it around.

1. Observe the effect of a gravitational lens on space-time. Take the graph paper and move the lens over the grid lines. How do the lines warp? (Inward? Outward? Circular? Square? Symmetrically?) If the grid lines represent space time, what is causing the distortion?

2. Draw a solid oval (galaxy) about the size of a square on an intersection of grid lines. As you move the lens about the galaxy, you will notice four configurations: an undistorted galaxy, a single distorted galaxy, two strongly distorted galaxies, and an Einstein ring.

a. Where is the galaxy (in relation to the lens) when it is undistorted (and still under the lens)?

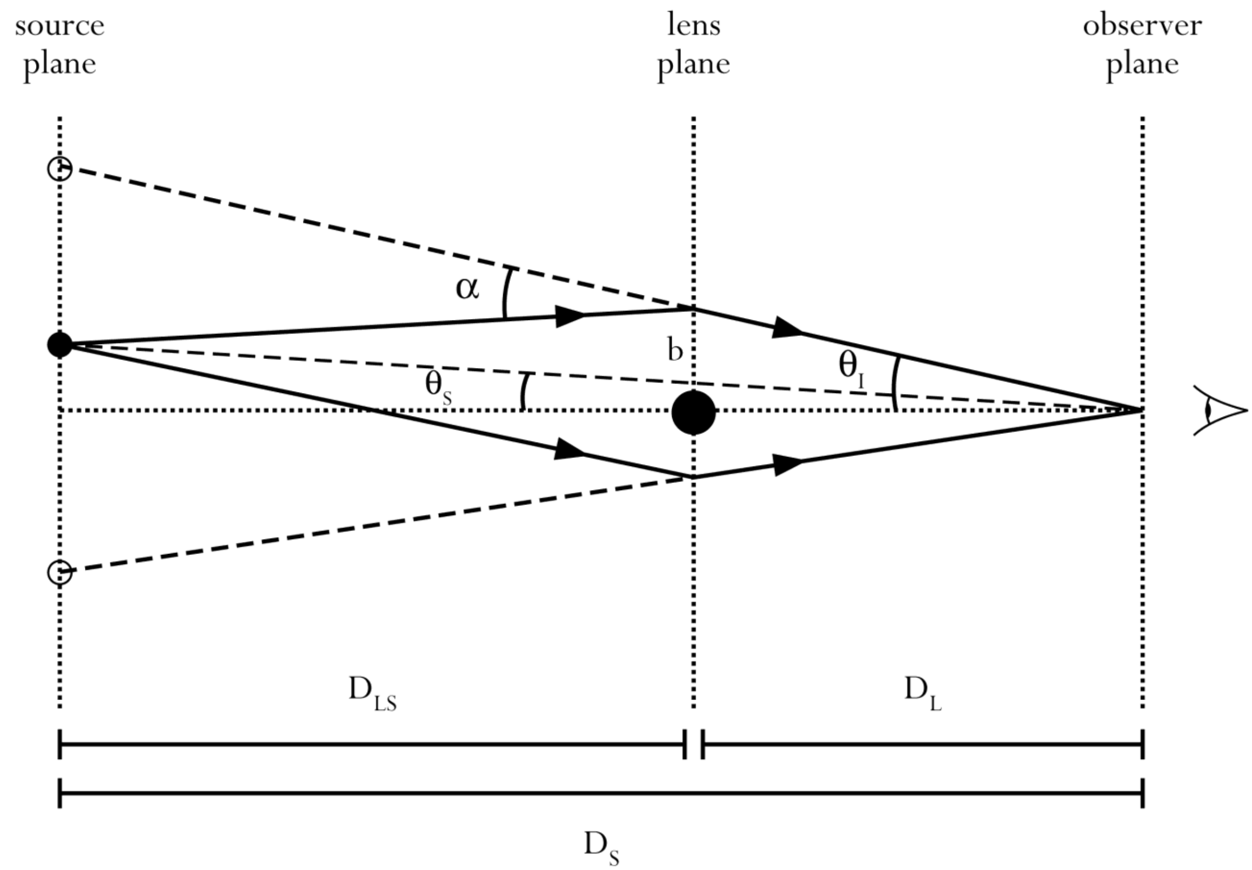
b. Where is the galaxy when it is distorted, but you only see one image of it?

c. Where is the galaxy when you see two images of it?

d. Where is the galaxy when you see an Einstein ring?

3. As you move the lens about the galaxy, does the galaxy stretch with the space-time lines?

Geometry of a gravitational lens



D_L = Distance from your eye to the lens
D_{LS} = Distance from the lens to the paper (the source)
D_S = Distance from your eye to the paper (the source)

4. Now you will observe the effect of distances between your eye, the lens, and the source (paper). Line up the lens (on the paper) to make an Einstein ring. Do this before every step (a, b, & c).

a. What happens to the size of the ring when you lift the lens, but keep your eye in place? Which variables (D_L , D_{LS} , and D_S) change? Which remain constant?

b. What happens to the size of the ring when you lift your eye, keeping the lens in the same place? Which variables (D_L , D_{LS} , and D_S) change? Which remain constant?

c. What happens to the size of the ring when you lift your eye and the lens together, keeping the distance between the two constant? Which variables (D_L , D_{LS} , and D_S) change? Which remain constant?

5. Now examine the HST Deep Field Image. Place the lens somewhere on the image.

a. Describe the change that occurs in what you see (with and without the lens).

b. Given what you've learned, describe how one could look for black holes in space using gravitational lensing.

6. Write your own question(s), and experiment to find the answer!